FIG. 1A



FIG. 1B

10

26    22    24    20

pH  temp dO2

14
20
16    20
24

56

34  58

28    12

32    30

upstream    downstream

34    32

36

46
40    40
Drive system unit :
P₁    six computer controlled    P₂
independent linear actuators

48

P₃  42    42  P₄

Fig 1C

26   22   24   18

pH   temp

14   CO2 in
CO2 out
media port

38

58

32   28   12   30

upstream   downstream

34   36   34

34

40   40

44

**Drive system unit:**
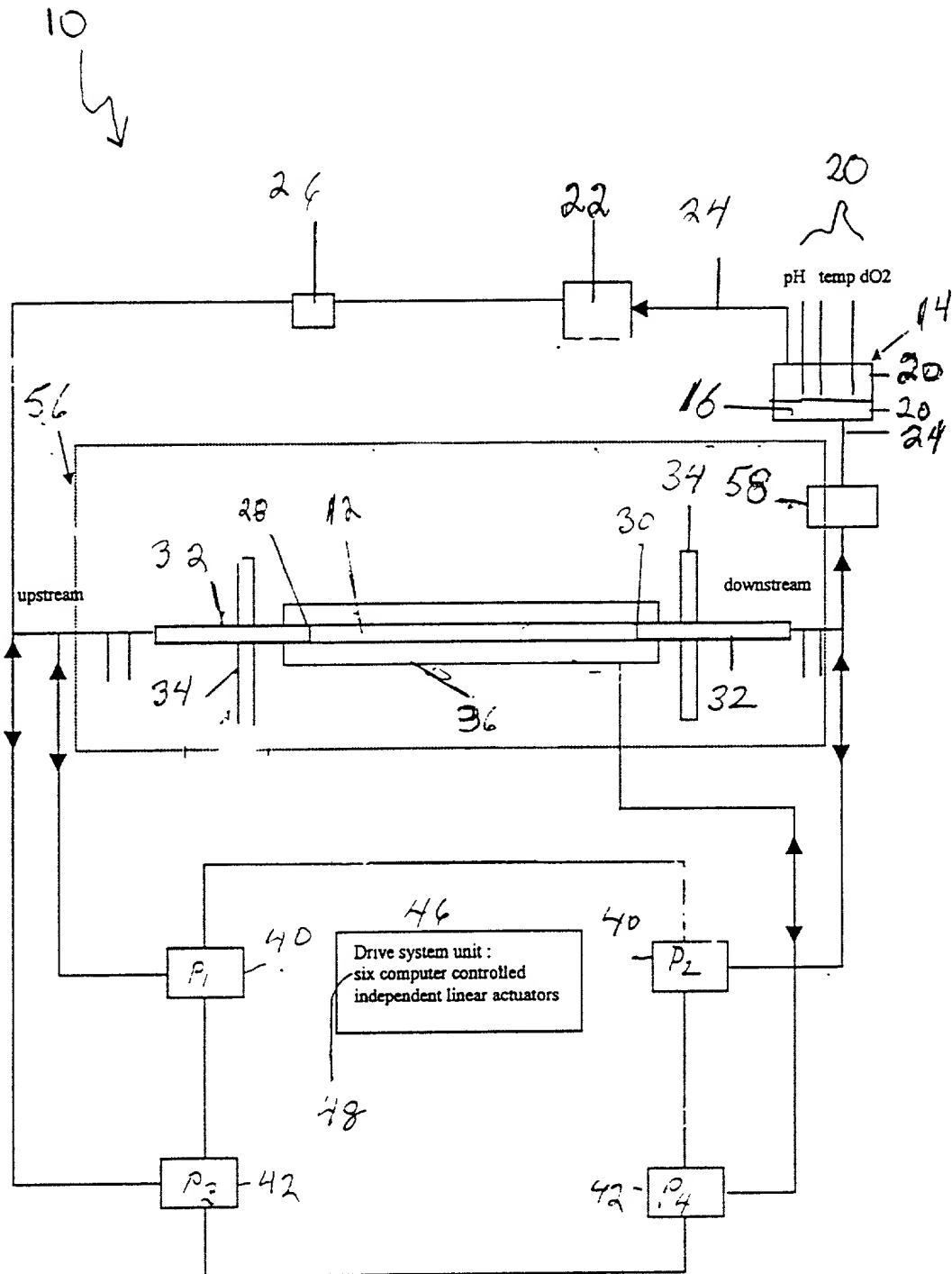six computer controlled
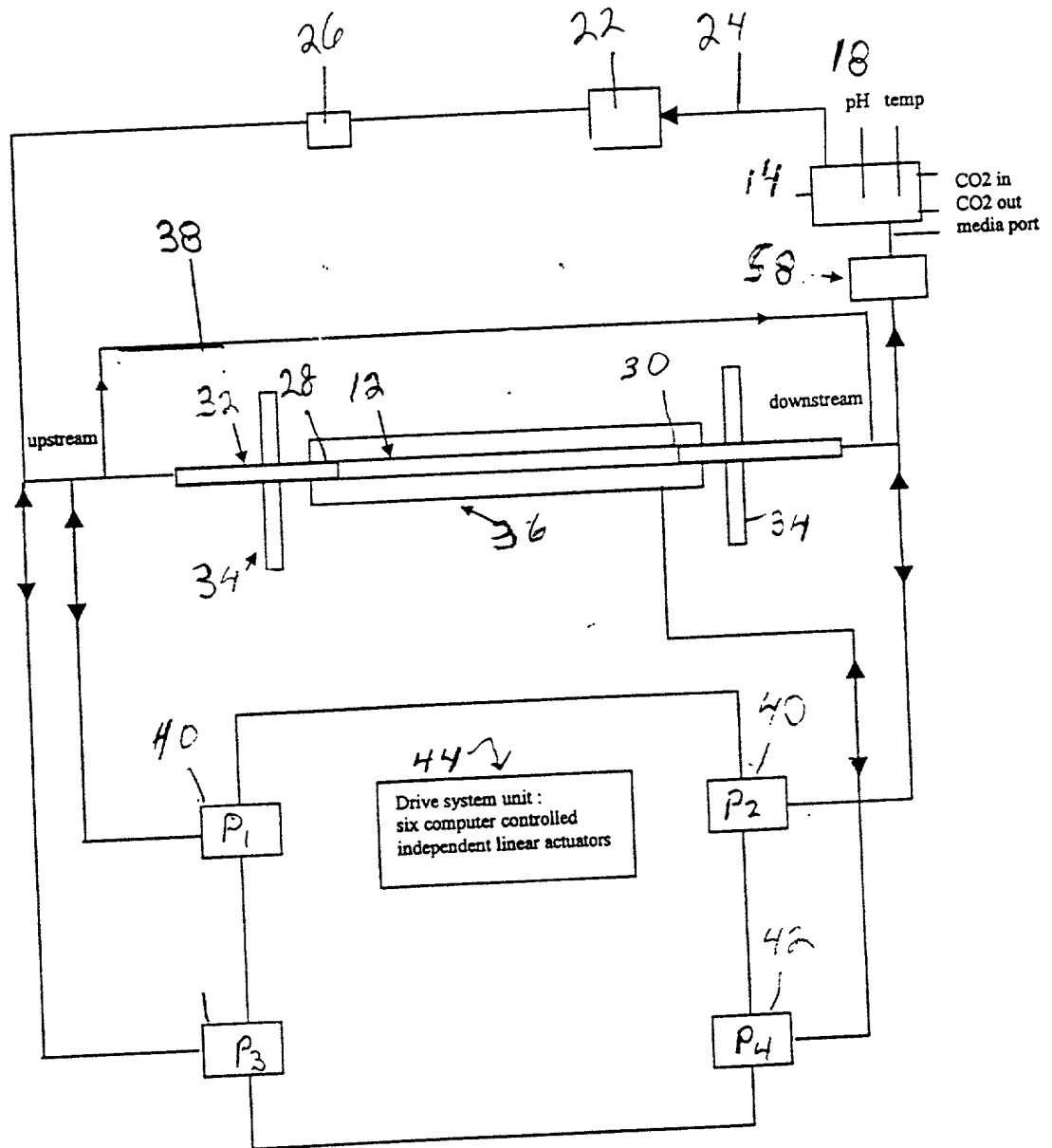independent linear actuators

P₁   P₂

42

P₃   P₄

Fig. 1D

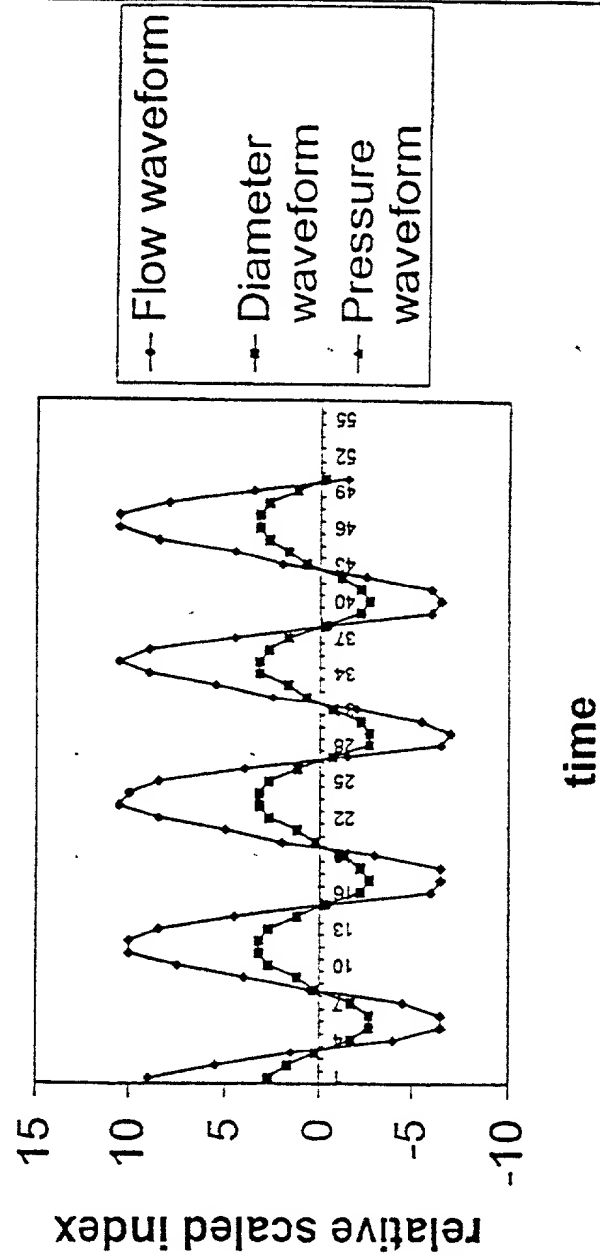Figure 2. 0 degree PHASE DIFFERENCE (SPA)

Figure 3. 60 degree PHASE
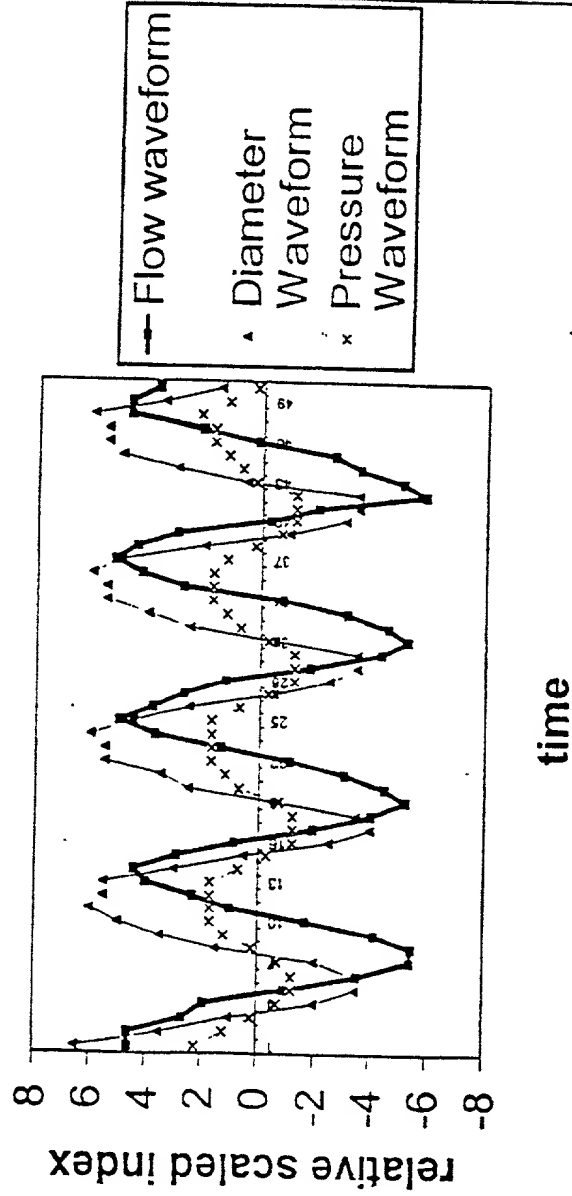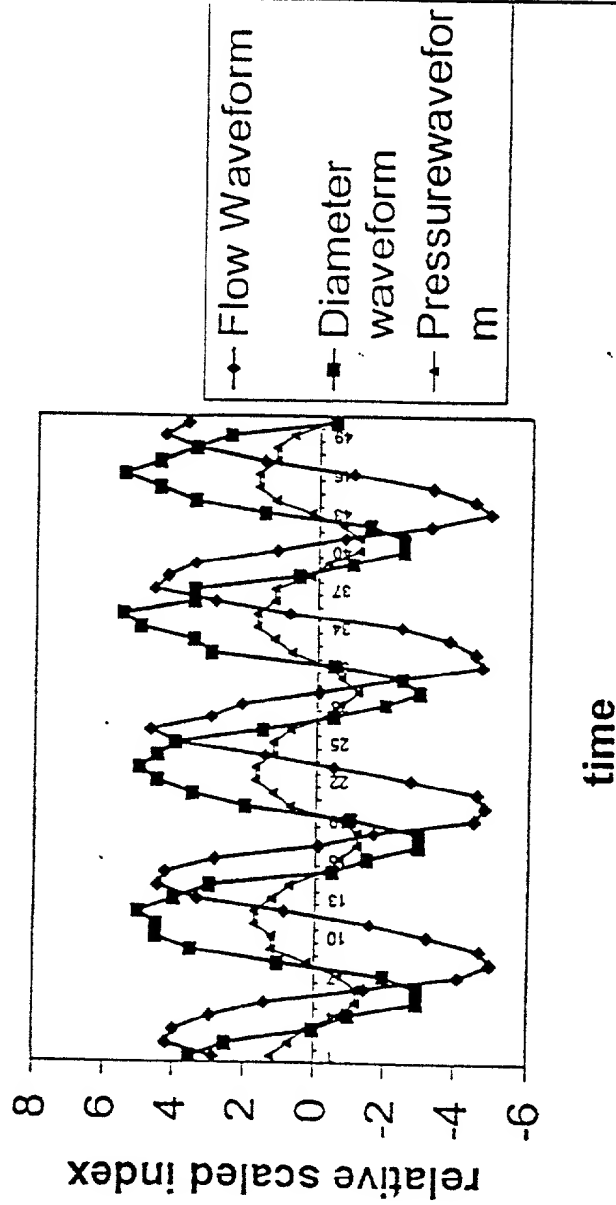DIFFERENCE (SPA)

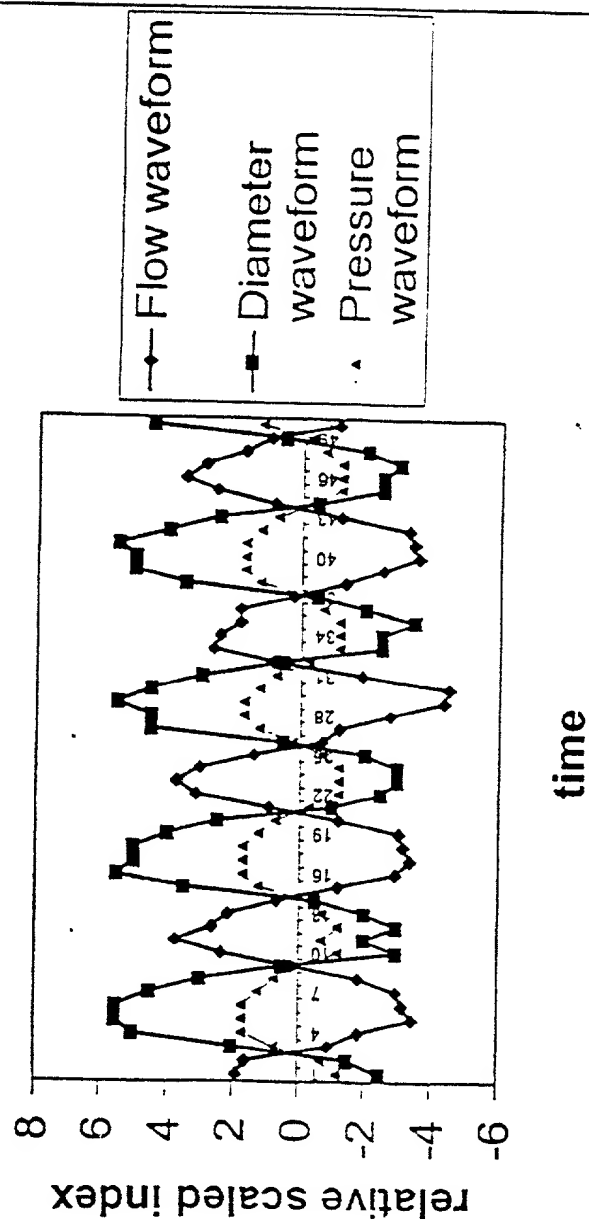## Figure 4. 90 degree PHASE DIFFERENCE (SPA)
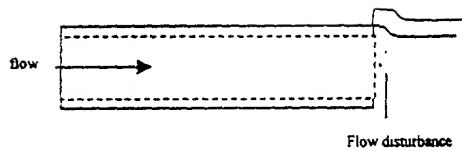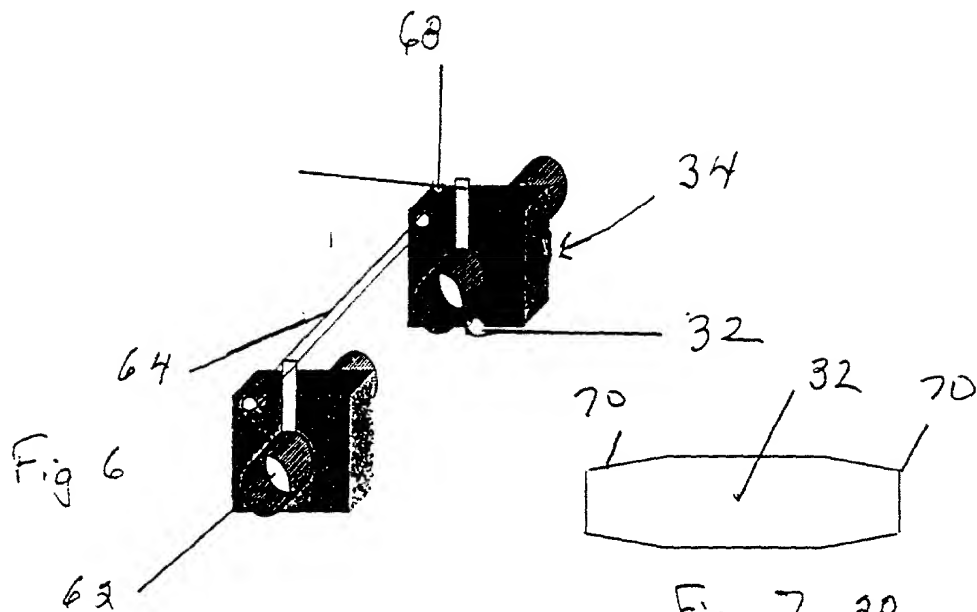
Figure 5 180 degree PHASE DIFFERENCE

Legend: Flow waveform; Diameter waveform; Pressure waveform

x-axis: time

y-axis: relative scaled index

68

34

64

32

Fig 6

62

70    32    70

Fig. 7

28    12

flow

Flow disturbance

negligible flow disturbance

32

Fig. 8A

Fig. 8B

A

B

Fig. 9

Fig 10